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PROBLEM-SOLVING IN DIFFERENT FIELDS OF ENDEAVOR

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By MARION LEROY BILLINGS, Western Kentucky State Teachers College

The term reasoning, like many other terms in psychology, has been used with a variety of meanings. It will be the purpose of the first part of this paper to discover the essentials of reasoning by reviewing the literature on the subject and then to conclude with a definition. The second part will give the data and conclusions of experiments dealing with "problem solving" in eight different academic fields.

The belief in mental faculties as separate entities promoted by the phrenologists and their followers is gradually giving way to the belief in general mental functions. That is, memory, for example, is a general function of the whole brain rather than any limited part of it. This belief is supported by the experiments of such men as Franz¹ and Lashley.² Lashley maintains, as a result of his experiments on rats, that the brain operates as a whole, and a habit which has been thoroughly established may be taken over by other parts of the brain, and perhaps, by the brain stem. He also concludes from his experiments that with any general or complex type of behavior the amount lost in the behavior by the removal of parts of the brain is in direct proportion to the amount of the brain removed without reference to the location. Such experiments tend to refute the idea of highly localized functional areas for the higher and more complex functions. Thus, we may conclude from a study of such experimental evidence that the various functions of the brain are very general functions involving probably the whole cortical portion if not the brain stem.

This conception of the brain and its functions does not imply, however, that the different functions such as memory, imagination, and reasoning may not vary greatly in their relative efficiency in the same individual.

* Accepted for publication August 12, 1932. This experiment has been carried through three different times: once at the University of Michigan in 1929, the results of which were submitted as a dissertation in partial fulfillment of the requirements for the degree of Doctor of Philosophy, and the other two times at the Western Kentucky State Teachers College in 1930 and 1931.

The author wishes to acknowledge his indebtedness to Professors W. B. Pillsbury and Carl Spearman and others who aided in the experiments and in the preparation of the manuscript.

¹S. I. Franz and K. S. Lashley, The retention of habits by the rat after destruction of the frontal portion of the cerebrum, *Psychobiol.*, 1, 1917, 3-18.

²K. S. Lashley, *Brain Mechanism and Intelligence*, 1929, summary, 175-6.

That the brain functions as a whole does not oppose the idea that a given brain may vary markedly in its capacities to receive, to retain, or to relate. A certain brain may receive without retaining, or it may retain and recall without being able to relate; that is, to use in solving problems; but, if it retains well in one academic field, as this is a general function, it ought to retain well in any other, other things being equal. In other words, retention does not differentiate in favor of any field of material. Likewise, the brain that is apt in relating in one field may be relatively as efficient in all other fields, other things being equal. Therefore, the writer launched these experiments to test the thesis, "That a person will be as good a reasoner in one academic field as another providing he has an equal background."

ESSENTIALS OF REASONING

In order to secure a definition of reasoning consistent with the various authorities and to discover the conditions of reasoning, the steps in reasoning, and the essentials or nature of the reasoning process, the literature on reasoning has been reviewed.³ As a result of this review we may make the following summary.

(1) The essential conditions for reasoning are: first, a problem; secondly, sufficient experiences with which to solve the problem; and thirdly, the individual must possess sufficient ability to rearrange those experiences in new relations to meet the new situation.

(2) The formal steps in reasoning as found in the literature are: a problem; an understanding of the problem, or judgment; the solution of the problem, or inference; a conclusion; a belief in the conclusion; verification; proof; and application. From the psychological point of view, the last three are not parts of the real reasoning process; but are follow-up processes for the purpose of testing or checking up on the conclusion, which really ends the reasoning process. Verification is but supplementary proof; application is but practical proof; and induction and deduction are the logician's method of proof.

(3) Thus, we may conclude that the essentials of reasoning may be reduced to: a problem, an understanding of the problem, and the solution of the problem, which presupposes essential experiences and ability.

(4) Finally, we may define reasoning as the solving of a practical or theoretical problem or difficulty by the use of or through the relating of past experiences, the end result of which is believed, no matter how fallacious or inconsistent it may seem to others. One accepts it as true because it is consistent with what one knows. (Frequently, our Ss who failed completely in solving the problems were very positive of their results.)

³ A fuller treatment of this subject may be obtained from the University of Michigan in the original thesis.

EXPERIMENTS IN PROBLEM-SOLVING

Object. The following experiments were planned to test the assumption that problem-solving, which involves the mental relating of experiences, is a general function and constant within a given individual, other things being equal.

To do this 146 Ss in groups of 50, 46, and 50 were ranked according to their ability to solve problems in eight academic fields: geometry, arithmetic, physics, mechanics, economics, sociology, geography, and history. In order to test ability and not past experiences, all of the materials necessary for solving the problems in each of the fields were thoroughly taught. Then the ability to solve problems with these materials was tested according to the usual classroom procedure. The Ss were allowed to use only the materials taught for solving the problems. If other materials were used, the solutions were not counted.

MATERIALS AND TECHNIQUE

Material. The following are fair samples of the various kinds of materials used:

Geometry. If a line from the vertex of an isosceles triangle is perpendicular to the base, prove that it bisects the base and the vertex angle.

Prove that the bisector of the exterior angle at the vertex of an isosceles triangle is parallel to the base.

At noon, a flag pole casts a shadow 56 ft. along the ground. How tall is the pole? The only instrument that you are allowed to use is a yard stick. When the yard stick is stood up along side and parallel to the pole it casts a shadow 16 in. long. The ground is level and at right angle to the base of the pole.

Arithmetic. A steer dresses away 35%. If it weighs 877.5 lb. after it is dressed what did it weigh alive?

What should be the selling price per pound for a blended coffee blended in the following way: 20% of 50¢ coffee, 33 $\frac{1}{3}$ % of 60¢ coffee, and 46 $\frac{2}{3}$ % of 30¢ coffee?

The freezing and boiling points on a Centigrade thermometer are 0° and 100° respectively. The same points on a Fahrenheit thermometer are 32° and 212° respectively. What will be the reading on the Centigrade thermometer when the reading on the Fahrenheit thermometer is 72°?

Physics. What effect will a double concave lens have on the direction of propagation of two parallel rays of light? Why is this so?

A locomotive passes an observer. The pitch of the whistle changes as it goes away. Does the pitch rise or lower? Why?

A steamboat has a water displacement of 1000 cubic feet; the boat itself weighs 5 tons; how many tons of cargo can the boat support?

Mechanics. In the transmission of an automobile are three gears arranged on the drive shaft from the engine from front to back: an 8 in. gear, a 6 in., and a 4 in.; and on the drive shaft leading to the differential in the same manner: a 4 in. gear, a 6 in., and an 8 in. (In the original the mechanism of the transmission and the differential were drawn.)

(a) Which two gears would you mesh to get the greatest power at the wheel?

(b) Which two gears would you mesh to get the greatest speed of the wheel?

(c) With the same gears meshed, which would give the greatest speed along the road, a 26 in. wheel or a 32 in. wheel?

(d) With the same load, which size wheel will take the most power to drive, the 26 in. or the 32 in.?

(e) Suppose that your car is standing on an incline headed down hill. You are going to start your engine by allowing your car to coast down the incline. Which gears will you mesh in order to have your engine start the easiest?

Economics. "Internal commerce does not increase the wealth of a nation since it only transfers goods from one person to another." Is this sound? Why?

"If the wheat crop of the world should fall off one half next year, a rise in price would be of a great social advantage." Is this sound? Why?

Why is a monetary system based on a bi-metallic standard unsatisfactory?

Sociology. Why is the rule of the Clergy in Civil Society objectionable?

Why is organized and synchronized work in education and industry apt to cause many human failures?

Why is competition (struggle) in society, on the whole, a beneficial process?

Geography. Why is the earth cold at the poles and hot at the equator? (This is not due to the poles being farther from the sun).

What would be the most evident effect if the axis of the earth was not inclined to its plane of revolution?

What is happening in our meteorological conditions when the winds shift in the following way: N.E. to N. to N.W.?

History. Why did the New England states become manufacturing states and the Southern states agricultural states?

How could Whitney's invention of the cotton-gin in 1792 be given as one of the causes of the Civil War?

What effect did the Emancipation Proclamation have on England's behavior toward the South? Why?⁴

Procedure. (1) *Instructions.* Printed instructions were placed in the hands of the Ss before every test. To insure uniformity of understanding, E read them aloud to the Ss and explained such details as were necessary. The instructions were as follows:

Please remember that your value as a subject in this experiment depends upon your faithfully carrying out the instructions given you. The purpose of this experiment is to obtain reliable data for whatever conclusions it may warrant. Your contribution to the results will depend upon your putting forth each time your best efforts. (1) You will be presented with some material which you will try your best to master. (2) You will be given some questions to answer to test how well you digested the material. (3) You will be given some problems to solve based upon this material. After the experiment has been finished, the aim and results will be given you.

Avoid worrying while working on the material. You will not be expected to get all of the problems; that is, not all of you. What is expected of you is that you do your very best. Consistent effort throughout the experiment is what will give the best results rather than solving every problem.

If any of the problems are so familiar to you that you do not have to solve them, that is, you do not have to think them through but you can put down the answer from memory, indicate this in writing in the margin beside the problems. It may be that you have had something similar before, but if enough time has elapsed so that you actually have to work the problems through again to solve them, then they are the same as new. Only in the cases that you know the answers without having to work the problems through will you indicate that you did not have to solve them.

⁴ An attempt was made to avoid as far as possible an overlapping of subject matter, such as arithmetical computations in geometry, physics, economics, etc.

You will accept the material taught as true for the solving of the problems. We wish to test your ability to use the material as given.

You will use *only* the materials taught for the solution of these problems. The reason for this is that we want all of you to work with the *same* materials and we wish to see how well you can do with materials as taught.

Special instructions for the problems in practical mechanics.

When working the problems in practical mechanics do not motion out the solutions with the hands and do not use pencil and paper excepting as indicated. Make a complete solution of a problem in your head before you make a mark; and then do just what is asked of you and no more. Avoid erasing if possible. Be sure that you have your solution and then put it down. Further instructions will be given later.

(2) *Individual information.* The Ss were required to fill out blanks after every test period, giving the following information about themselves: name; sex; time consumed in solving the problem; year in college; previous preparation in the subject tested in semester hours in high school and in college.

(3) *Routine of work.* The material for each subject was thoroughly taught on Monday afternoon from 4-6 o'clock, or longer if needed. The Ss were held until they thoroughly understood everything that had been presented. Much of the material was simple and only a review for most of the Ss; but nothing was taken for granted. An outline of the material presented in each subject was given to each S so that the work might be reviewed before the test and vague points cleared up.

On Wednesday afternoon of the same week, from 4-6 o'clock, the tests were given. For the first 15 min., or more if needed, the Ss answered a true-false test on the subject matter to determine whether or not they had mastered the information presented. Most of the Ss were through with this in 5 min. If any points were unclear, they were explained and then the Ss were given the problems with these final instructions.

You will have but one hour to work on the problems, but do not worry about the amount you are getting done, just work as rapidly as is consistent with accurate work; you may work them in any order that you please; and you are to use for your solutions nothing but the material taught on Monday. Any fact which you have forgotten or of which you are not sure that is essential in the solution of a problem will be supplied you. You are to put down on your test paper all of your work; just answers do not count. Put down each step in your solution, for it is the solution in which we are interested and not merely the answer. Do not quit until the hour is up unless the problems have all been solved. Keep on trying.

(4) *Evaluating the solutions.* The steps necessary in the solution of each problem were decided upon by E in collaboration with two professors in each of the subjects tested. Two methods of evaluating the solutions given by the Ss were tried: an 'all-or-none' method (*i.e.* all right or all wrong), and a partial value method (*i.e.* giving part credit). Since it made little difference in the final outcome which method was used we evaluated the solutions by taking each step into account. If all the steps were correct, the solution was given full credit even though the final answer was wrong. Our interest was in the solution and not in the answer. Frequently answers would be far wrong because of errors in simple calculations while the principles of the solutions were entirely correct.

The relative difficulty of the problems and the values assigned them were determined as follows. If a problem was solved by all of the Ss it was given the lowest rank, 0. If 90% of the Ss solved it, it was ranked as 10; if 80% solved it, it was

ranked as 20; if 50%, as 50, and so on throughout the entire list of problems. After the problems had been ranked, arbitrary values were assigned them so as to bring the total number of points to 120. This was done, in lieu of standardized tests, in order to make them as objective as possible.⁵

(5) *Attitude of the Ss.* The general attitude of the Ss was good. A few who did not take the work seriously were excused after the second meeting; the rest entered into the spirit of the experiment and worked hard.

(6) *Subjects.* Of those completing the tests, the first group was made up of 30 men and 20 women, the second group of 24 men and 22 women, and the last group of 18 men and 32 women—146 Ss in all. They were selected almost entirely from the classes in psychology in the University of Michigan and the Western Kentucky State Teachers College. There were 12 seniors, 34 juniors, 58 sophomores, and 42 freshmen.

RESULTS

(a) *Subject matter.* The subject matter or information taught was well mastered. From 23 to 36 'true-false' questions were used to test the S's knowledge of each of the subjects taught. An average of only 2.22 questions was missed on all of the tests.

(b) *Problem-solving.* The tables below give the correlations between every two of the eight academic subjects used in this study. It will be noted (1) that these correlations are moderately high and constant, and (2) that the inter-correlations between the science and the humanitarian groups are about as high and as constant as the intra-correlations within each of these groups.

Some of the correlations were lowered by the following factors over which we had no control.

(1) The correlations were most affected by the fact that many of the Ss were taking college courses in the subjects employed in this study; for example, of the first group of Ss, 13 were taking courses in economics, 10 in sociology, 10 in history, 4 in physics, 3 in geography, and none in geometry or mechanics. The other groups of Ss gave similar results. In order to demonstrate the effect of simultaneous study upon the correlations, the Ss taking economics and sociology were omitted, and a few of the correlations were recomputed. The correlation between geometry and economics rose from 0.55 to 0.69; between arithmetic and economics, from 0.60 to 0.67; between mechanics and economics, from 0.65 to 0.74; and between geometry and sociology, from 0.41 to 0.69. These values are given in parentheses in Table I.

(2) Another factor which affected geometry slightly was the inaccuracy in calculations; e.g. in some cases errors were made in calculating the degrees of the angles not given in the problems, which made the solutions of the problems impossible with

⁵ We had hoped to use standardized tests in these experiments, but we were unable to find any that were suitable. Few tests are concerned with problem-solving, most are based on memory—even in mechanics and physics, the task usually set is to identify or label parts or wholes.

the material given. Had these angles been correctly calculated, the solutions would have been comparatively easy.

TABLE I

CORRELATIONS FOR FIRST GROUP OF Ss

	Geom.	Arith.	Physics	Mech.	Econ.	Soci.	Geog.
Arithmetic	.69						
Physics	.66	.77					
Mechanics	.65	.67	.77				
Economics	.55 (.69)	.60 (.67)	.69	.65 (.74)			
Sociology	.41 (.69)	.59	.65	.65	.72		
Geography	.48	.58	.68	.60	.57	.62	
History	.58	.60	.63	.65	.69	.78	.56

TABLE II

CORRELATIONS FOR THE SECOND GROUP OF Ss

	Geom.	Arith.	Physics	Mech.	Econ.	Soci.	Geog.
Arithmetic	.78						
Physics	.73	.79					
Mechanics	.47	.57	.66				
Economics	.69	.74	.77	.54			
Sociology	.67	.74	.78	.57	.90		
Geography	.61	.72	.84	.68	.77	.81	
History	.60	.70	.81	.61	.80	.89	.86

TABLE III

CORRELATIONS OF VALUES FOR ALL THREE GROUPS TOGETHER
(Raw correlations without corrections)

	Geom.	Arith.	Physics	Mech.	Econ.	Soci.	Geog.
Arithmetic	.76						
Physics	.78	.75					
Mechanics	.61	.63	.77				
Economics	.70	.66	.78	.59			
Sociology	.64	.69	.78	.65	.86		
Geography	.59	.68	.77	.69	.71	.75	
History	.53	.65	.63	.56	.66	.75	.68

(3) A third factor which affected the results slightly was the fact that two of the Ss did not follow the instructions. For example, one S who was antagonistic to the social principles taught spent the most of the hour attacking those principles rather than trying to solve the problems. Thus, this S ranked high in everything but sociology. In an interview later, he had no difficulty in solving the problems.

In the opinion of the writer these correlations are very significant considering all of the factors contributing to lower them. Besides those mentioned above, the following could not be entirely eliminated in a laboratory experiment: (4) earlier established attitudes; (5) short periods for instruction, and (6) the specializing of some of the Ss in some of the academic subjects.

(c) *Coefficient of reliability of the problem-solving tests.* Spearman has recommended, when a test cannot be repeated that the odd problems be correlated against the evens and then applied to the formula: $r_s = 2rh/(1 + rh)$. This has been done, and the following table gives the raw correlations and the coefficients of reliability for each of the tests according to this formula.

(d) *Correction of coefficients of correlations for attenuation.* The coefficients of correlation for problem-solving given in Table III have been connected for attenuation according to Spearman's formula and are given in Table V.

TABLE IV
COEFFICIENTS OF RELIABILITY FOR THE PROBLEM-SOLVING TESTS

Subject	Raw correlation	Coefficient of reliability
Geometry	.85	.918
Arithmetic	.81	.895
Physics	.67	.802
Mechanics	.82	.901
Economics	.78	.876
Sociology	.74	.850
Geography	.75	.856
History	.52	.684

(e) *Individual rankings.* In order that the details of the experiment may be presented more clearly, the data have been analyzed further by giving the ranking of 10 Ss, selected haphazardly from the first group, in each of the eight academic subjects. Number 1 represents the highest rank and 50 the lowest.

TABLE V
CORRELATIONS OF TABLE III, CORRECTED FOR ATTENUATION

	Geom.	Arith.	Physics	Mech.	Econ.	Soci.	Geog.
Arithmetic	.83						
Physics	.90	.88					
Mechanics	.67	.70	.90				
Economics	.77	.74	.92	.66			
Sociology	.72	.79	.95	.74	1.00		
Geography	.65	.77	.92	.78	.82	.83	
History	.79	.83	.86	.72	.85	.98	.88

TABLE VI
RANKING OF 10 Ss OF THE FIRST GROUP

S	Geom.	Arith.	Physics	Mech.	Econ.	Soci.	Geog.	Hist.
2	49*	47*	40	44	40	44	36	35
4	43	48	47	48*	47	36†	41	42
6	46	50	50	49	40*	37	49	34
12	42	43*	49	43	46	42	29	46
21	50	43*	41	48*	44	40	44	50
31	49*	47*	46	50	50	50	50	49
49	1	1	4	6	3	31‡	3	2
25	7	2	3	2	25§	1	1	3
26	3	10	19	10	11	13	5	11
28	12	13	1	5	1	4	2	4

* The reason for 2 Ss getting the same rank is that they obtained the same score in these tests.

† This S was taking sociology at the time of this experiment.

‡ This S is the one who attacked the principles of sociology instead of solving the problems.

§ This S received a grade of 70 in economics, which was a fair score; but it gave him a low rank because of the large number that were taking economics at the time and were crowded toward the top.

In only a very few cases did an *S* who ranked in the first quartile of one subject get into the fourth quartile of another and vice versa.

(*f*) *Information and problem-solving.* The following correlations were obtained between rank in information and in problem-solving: in geometry, 0.37; arithmetic, 0.35; physics, 0.59; mechanics, 0.49; economics, 0.47; sociology, 0.45; geography, 0.51; and history, 0.38. These correlations are lower on the whole than those obtained between the various problems.

An analysis of the data shows that the *Ss* who were able to solve the problems had the required information, but not all the *Ss* who had the information were able to solve the problems. The ability to solve the problems does not vary directly with the amount of information. As one *S* (a woman) reported, "I can learn all that you teach in a few minutes but I do not seem to be able to apply it in solving the problems"; and her results bore out the truth of this statement. She ranked among the highest in information, but only among the average in problem-solving. Furthermore, some of the *Ss*, who made a poor showing in the information tests, did as well and in some cases better in problem-solving than other *Ss* who stood high in information. Some *Ss* cannot use what they know, while others use the knowledge they have to good advantage. One *S*, for example, of the first group was among the 6 lowest in information and the 12 highest in problem-solving.

(*g*) *Effect of sex.* Table VII shows that on the average the men ranked but a little higher in information and general intelligence, as measured by the Army Alpha Test, than the women but, in problem-solving, their average score was 48.7% above that of the women.

TABLE VII
A COMPARISON OF THE SCORES MADE BY THE MEN AND WOMEN

Sex	Av. score information	Av. score prob.solving	Av. Army Alpha	Av. I.Q.
Women	84.9	39.6	127.68	108
Men	90.2	58.9	141.76	114
Diff.	5.3	19.3	14.8	6
% diff.	6.2	48.7	11.0	5.5

(*h*) *Correlations between problem-solving and the Army Alpha Test.* The following coefficients show that there is a higher correlation between the problem-solving in these eight fields and the Army Alpha test than between the information tests in the eight fields and the Army Alpha.

(a) Coefficients of correlation between problem-solving in the eight fields and the Army Alpha Test are: geometry, 0.51; arithmetic, 0.58; physics, 0.55; mechanics, 0.59; economics, 0.42; sociology, 0.53; geography, 0.50; and history, 0.54.

(b) Coefficients of correlation between the information tests in the eight fields and the Army Alpha Test are: geometry, 0.31; arithmetic, 0.34; physics, 0.40; mechanics, 0.53; economics, 0.41; sociology, 0.19; geography, 0.39; and history, 0.31. This is probably due to the fact that 120 of the 212 points of the Army Test are scores for reasoning or seeing relations. The rest of the points are for information.

We find higher correlations between these 120 points and problem-solving of the eight academic subjects than with the information tests. Also, we find them higher than with the Army Test as a whole. (1) Coefficients of correlation between the 120 points of the Army Test and the problem-solving of the eight academic subjects are: geometry, 0.61; arithmetic, 0.68; physics, 0.69; mechanics, 0.64; economics, 0.59; sociology, 0.58; geography, 0.50; and history, 0.57. (2) The coefficients of correlation between the 120 points of the Army Test and the information test of these eight subjects are: geometry, 0.43; arithmetic, 0.32; physics, 0.43; mechanics, 0.52; economics, 0.34; sociology, 0.10; geography, 0.32; and history, 0.33.

(i) *Correlations with previous preparation.* In order to meet the criticism that the solutions of these problems might have been unduly influenced by previous training, correlations have been worked out between the solving of the problems and the previous preparation of the Ss in semester hours in each of the subjects, except mechanics. Mechanics was excepted because of shop work, factory work, and home work which could not be reduced to semester hours. The average coefficient of correlation for the remaining subjects is 0.26 ranging from -0.17 to 0.53 as follows: geometry, 0.43; arithmetic, 0.50; physics, 0.53; economics, 0.30; sociology, -0.17 ; geography, 0.17; and history, 0.09.

The preparation in mathematics of various individuals varied from 12 to 36 semester hours, in physics from 0 to 15, in economics from 0 to 9, in sociology from 0 to 18, in geography and related subjects such as geology and physiology from 0 to 12, and in history from 6 to 36.

To show how little previous training influenced the results of these experiments, under the conditions given, the following 5 cases are cited. One S who had had no previous preparation in sociology received the highest score, and two others who had had no sociology tied for second and third places in problem-solving. Also, 2 Ss who had had no previous preparation in geography made the highest scores in this subject. An exception to this general rule must be made in the cases of mathematics and physics. There is a higher correlation between these subjects and previous training, which may be due to the fact that students who are good in problem-solving elect these courses, since they are usually taught by the problem method and hence would be attractive to them.

(j) *Correlations with honor points.* There is a relatively low correlation between the average number of honor points earned in the University of Michigan and the scores made in solving the problems in these eight fields. The following are the coefficients of correlation: geometry, 0.34; arithmetic, 0.38; physics, 0.42; mechanics, 0.32; economics, 0.20; sociology, 0.42; geography, 0.42; and history, 0.32.

These results also show that those who received high honor points generally solved the problems, but the contrary is not true, not all of those able to solve the prob-

lems received honor points. This may be due to a number of factors of which the following three are but suggestions. (1) It may be due to the fact that many of the undergraduate courses are fact gathering courses; (2) it may be due to personal prejudices; or (3) it may be due to the fact that some of these students were not applying themselves to their university work.

The coefficient of correlation between the average scores made on the information tests in these eight subjects and the average honor points earned in the University of Michigan is 0.60. The coefficient of correlation between the average number of honor points and the Army Alpha scores is 0.50.

(*k*) *Criterion of the tetrad equation.* The correlations between the marks of school subjects, etc., tended toward an arrangement, which can be expressed in Spearman's tetrad equation.⁹ He says:

Whenever the tetrad equation holds throughout any table of correlations, and only when it does so, then every individual measurement of every ability can be divided into two independent parts which possess the following momentous properties. The one has been called the "general factor" and denoted by the letter *g*; it is so named because, although varying freely from individual to individual, it remains the same for any one individual in respect to all the correlated abilities. The second part has been called the "specific factor" and denoted by the letter *s*. It not only varies from individual to individual, but even for any individual from each ability to another.

Since these correlations meet the criterion of Spearman's "tetrad equation" it may be that problem-solving represents *g*, which Spearman says may be eventually appropriately called "intelligence."

SUMMARY OF CONCLUSIONS

This experiment has been repeated three times with consistent results during the last three years with three different groups of Ss. Though we have no wish to be dogmatic, the following conclusions and generalizations seem nevertheless to be warranted.

(1) Given a common background, there is a rather high correlation between the ability to solve problems in one subject and the ability to solve problems in another. The average of the 29 correlations is 0.67.

(2) The correlations between some of the problem-solving tests were lowered by various factors which could not be eliminated in these experiments; the main one of which was that many of the Ss were taking courses in similar subjects at the time of the experiments, especially economics, sociology, and history.

(3) These experiments show a lower correlation between information and the ability to solve problems in the same subject than between the ability to solve problems in different subjects. The average of these cor-

⁹ C. E. Spearman, *The Abilities of Man*, 1927, 73 f.

relations is 0.45. However, those who solved the problems knew the material, but not all of those who knew the material could solve the problems.

(4) These correlations, as a whole, show very little relation between the ability to solve problems and previous preparation unless the material has been studied within a year. This is probably due not so much to extra information as to the similarity of the problems. When problems are similar and past solutions are fresh in mind, the right association or Gestalt is much more apt to come.

(5) The data herein given would indicate that the best fact gatherers receive the greatest number of honor points.

(6) Although the women ranked nearly on a par with the men in the Army Alpha and information tests, they were unable to maintain that equality in problem-solving. The men scored 48.7% higher than the women.

(7) These correlations meet the criterion of the tetrad equation.

The results of this study seem to substantiate the view that "problem-solving" is a general ability, "factor," or function. Thus, an individual, other things being equal, should function in this capacity relatively as efficiently in one field as another.

Although the functionalists and Gestaltists⁷ differ in their general theories, these facts would accord with either of them if left to them to interpret. According to the first of these schools of psychology, problem-solving or the relating of past experiences to overcome a difficulty is a general function of the whole brain and depends upon the original mobility of the nervous system; while according to the second, especially to Köhler,⁸ these inner workings are explained by internal dynamics of the nervous system, which depend upon the original dynamics for functional unity and organization. Both of these schools of psychology would explain problem-solving on the basis of some inherent disposition of the nervous system; one by trial and error or sudden unexplained association and the other by the physiology of the nervous system or inner dynamics. By either theory, however, the solution of a problem will be immediate and will depend upon past experiences either in the form of associations or functional units called patterns or configurations. As Wertheimer says,⁹

⁷ Gestalt appears to be only a new interpretation or revised theory of association. Association is explained in functional wholes, configurations, or patterns as opposed to the serial, a-b-c, type of association.

⁸ W. Köhler, *Gestalt Psychology*, 1929, 103-149.

⁹ M. Wertheimer, *Über Schlussprozesse im produktiven Denken*, 1920, 1-22; *Drei Abhandlungen zu Gestalttheorie*, 1925, 1-84.

problem-solving or creative thinking is the successful transposition of a member of one configuration to another. These different configurations are identified as belonging to a common configuration. Thus, these results and these theories would seem to make problem-solving a general function dependent upon the innate capacity or dynamics of the nervous system.

It is possible to explain the other mental processes in a similar manner; that is, they are general functions or manifestations and depend upon the original disposition of the physical organism. This theory makes it easy to explain why the same individual may differ so widely in his relative ability in the different functions. A "low grade" may have an excellent rote memory without being able to relate his experiences into a construct or to transfer them from one Gestalt to another. Each is a different function or manifestation of the brain. A piece of lead may receive impressions and retain them, but it is incapable of relating those impressions into anything different. Likewise, with these different functions of the nervous system, impressions may be received and retained without being related or organized. Of course, relating cannot be carried on without something to relate. Although memory may be independent of reasoning or problem-solving, problem-solving is more or less dependent upon a good memory.

Since memory is the more general function and much more easily measured than reasoning, it is easy to understand how our schools might unconsciously drift into the habit of exercising and testing this function. This combined with the bad habits of study acquired by many of our bright students may explain why the students good in memory receive the most honor points.

Finally, let us inquire as to what we mean by intelligence. What is it that differentiates the lower forms from the higher, the more intelligent humans from the less intelligent, the genius from the average, if it is not the ability to meet "unprecedented situations"? Such men as Socrates and Edison had fewer opportunities to acquire information than we; yet they rose head and shoulders above us. Why? Not because of their phenomenal memories but because of their ability to solve problems with what they knew. Is it not, therefore, this ability to solve problems which the makers of intelligence tests are trying to measure? If it is, then they shall have to revise materially their tests.

It is evident that these makers of tests are not agreed; for example, one group—Otis, Pressey, and those who helped to make the Army Alpha Test—excluded memory tests; another group—Binet, Terman, and Thorndike—include them. Yerkes, in one of his tests, has 6 components out of 20 given to testing the imagination; and the Army Alpha Test allows

ninety-two points (tests numbered 1, 4, and 8) of its 212 points for remembered facts. Who are right? Are all of these processes intelligence or are they but different manifestations of a nervous system? It is a well known fact that the lower forms of organic life have organic memories, but these cannot be classified as intelligent. What, then, is intelligence, especially in humans? Is it the ability to remember, of which "low grades" may have a liberal allowance, or is it the ability to use the memory facts in a practical or theoretical way to solve problems and to unravel the riddles of the universe? Stern says,¹⁰ and the writer is inclined to agree with him, that intelligence is the mental power which produces conscious adaptations to new situations. Thus, it occurs to the writer that perhaps this series of tests or similar ones which will test the individual's ability to solve problems in the various fields of activity will be real tests of what we call intelligence and will some day replace the tests which deal with perception, memory, association, imagination, and muscular coördination.

In conclusion, we suggest that the ability to "solve problems," which is an important factor in Spearman's *g*, may be shown ultimately to be the distinguishing characteristic of, if not what we actually mean by, "intelligence" itself.

¹⁰ W. Stern, *The Psychological Methods of Testing Intelligence*, 1914, 3.

